CORROSION BEHAVIOUR OF METALS IN ARTIFICIAL URINE IN PRESENCE OF SODIUM CHLORIDE

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Corrosion resistance of two metals namely mild steel (MS), Nickel Titanium super elastic alloy has been evaluated in artificial urine in the absence and presence of sodium chloride. Potentiodynamic polarization study has been used to investigate the corrosion behaviour of these metals. The order of corrosion resistance of metals in artificial urine, in the absence and also in the presence of sodium chloride was Ni-Ti super elastic alloy > mild steel.

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Introduction

Titanium metal and its alloys are used in dental and orthopaedic implants on account of their excellent corrosion resistance, biocompatibility and osseointegration behaviour.[1-3]

Commercially pure titanium (CP-Ti) is widely used as an implant material. The biocompatibility and corrosion resistance of the titanium metals the result of passive TiO_2 films of thickness 2–6 nm formed on the titanium surface.[4-8] Many studies have been reported [9-13] to understand the corrosion mechanism of pure titanium in different biological media. Various surface modifications like anodic oxidation treatments,[14] electrochemical treatments,[15] sandblasting,[16] carbide coatings,[17] laser nitriding,[18] electrolytic polishing,[19] etc., on CP-Ti implants have been carried out to improve their corrosion resistance. The above techniques have shown to improve the corrosion resistance of CP-Ti. But the strength of these implants still remains an issue of concern. Stainless steels, titanium alloys and cobalt alloys are commonly used as biomaterials.[19-25] Now a days NiTi shape memory alloys are also introduced to clinical practice. The major advantage of these biomaterials refers to their unique properties, i.e. a thermal shape memory effect and a super elasticity. When shape memory alloys are considered as candidates to be applied in medical devices, they must be able to fulfil functional requirements related not only to their mechanical reliability but also to their chemical reliability (in vivo degradation, decomposition and dissolution, corrosion, etc.) and their biological reliability incompatibility, cytotoxicity, carcinogenicity, anti-thrombogenicity, antigenicity, etc. A great body of research was done to understand the mechanical and physiochemical properties to this extraordinary biomaterial and introduce it to clinical practice.[26-33]

In the present study commercially available sodium chloride was used. The present work was undertaken to study the corrosion behaviour of two metals namely mild steel (MS), Nickel-titanium super elastic alloy in artificial urine, in the absence and presence of sodium chloride by polarization study. Corrosion parameters such as corrosion potential, corrosion current and linear polarization resistance have been derived from these studies.

Materials and Methods

Two metals namely mild steel (MS), Nickel Titanium super elastic alloy were chosen for the present. The composition of mild steel was (wt %):0.026S, 0.06P, 0.4 Mn, 0.1 C and balance iron.[34] The composition of Ni-Ti super elastic alloy was (wt%) Ni 55.5, and balance Ti.[35] The metal specimens were encapsulated in Teflon. The surface area of the exposed metal surface was 1 cm^2. The metal specimens were polished to mirror finish and degreased with trichloroethylene. The metal specimens were immersed in artificial urine (AU),[36] whose composition was: Solution A: $CaCl_2.H_2O$-1.765 g L^{-1}, Na_2SO_4-4.862 g L^{-1}, $MgSO_4.7H_2O$ - 1.462 g L^{-1}, NH_4Cl - 4.643 g L^{-1}, KCl- 12.130 g L^{-1}. Solution :$NaH_2PO_4.2H_2O$ - 2.660 g L^{-1}, Na_2HPO_4- 0.869 g L^{-1}, $C_6H_5Na_3O_7.2H_2O$ - 1.168 g L^{-1}, NaCl -13.545 g L^{-1}.The pH of the solution was 6.5.[37] Just before the experiment, equal volumes of A and B were mixed and used as artificial urine.

In electrochemical studies the metal specimens were used as working electrodes. Artificial urine (AU) was used as the electrolyte (10 ml). The temperature was maintained at 37±0.1 ^{0}C. Commercially available sodium chloride was used in this study 50 ppm and 100 ppm of sodium chloride was dissolved in artificial urine.

Potentiodynamic polarization

Polarization studies were carried out in a CHI-Electrochemical workstation with impedance, Model 660A. A three electrode cell assembly was used. The working electrode was one of the two metals. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. From the polarization study, corrosion parameter such as corrosion potential (E_{corr}), Corrosion current (I_{corr}) and Tafel slopes (anodic = b_a and cathodic = b_c) were calculated.

Result and Discussion

Polarization Study

The polarization curves of mild steel immersed in Artificial Urine (AU) in the absence and presence of sodium chloride are shown in Figs 1 to 3. The corrosion parameters namely *LPR*, I_{corr}, E_{corr}, Tafel slopes (b_c= cathodic, b_a= anodic) are given in Table.1.when corrosion resistance of a metal in a medium increases, *LPR* (Linear polar resistance) value increases and corrosion current decreases.[38-48]

Table 1. Corrosion parameters of MS immersed in AU in absence and presence of sodium chloride obtained by polarization study.

System	E_{corr} mV*	b_c mV**	b_a mV**	*LPR* Ω cm^2	I_{corr} A cm^{-2}
AU	-0.651	183	208	11415	3.69x10^{-6}
AU+A	-0.697	146	207	8850	4.19 x10^{-6}
AU+B	-0.681	162	220	7793	5.19 x10^{-6}

AU=Artificial Urine; A=50ppm NaCl; B=100ppm NaCl; *mV vs SCE; ** mV in one decade.

It is observed from Table.1 that when 50ppm of sodium chloride is added to AU, the *LPR* value decreases from 11415 to 8850 ohmcm^2. Correspondingly the corrosion current (I_{corr}) increases from 3.69 x10^{-6} to 4.19 x10^{-6} A cm^{-2}. When 100 ppm of sodium chloride is added to AU, the *LPR* value further decreases to 7793 ohm cm^2 and the corrosion current (I_{corr}) increases to 5.19 x10^{-6} A cm^{-2}. In general it is observed that the corrosion resistance of MS inAU decreases in the presence of sodium chloride.

It is observed from the table that the corrosion potential shifts to cathodic side (more negative) in the presence of sodium chloride. Hence it is concluded that in presence of sodium chloride, the cathodic reaction is controlled predominantly.

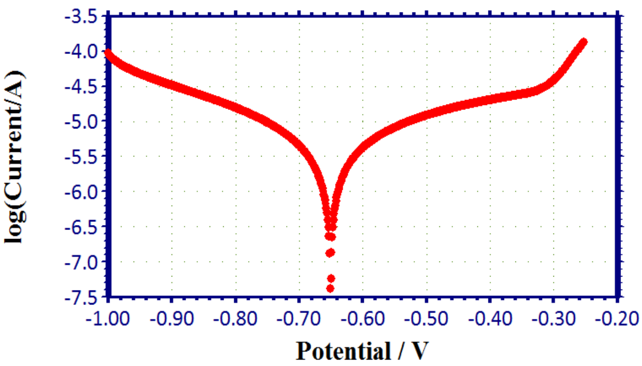

Figure 1. Polarization curves of MS is immersed in AU

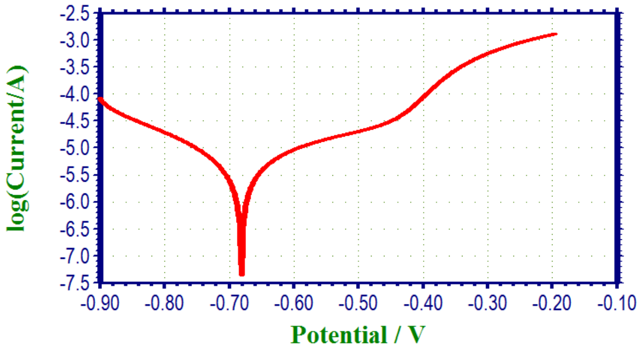

Figure 2. Polarization curves of MS is immersed in AU + 50ppm sodium chloride

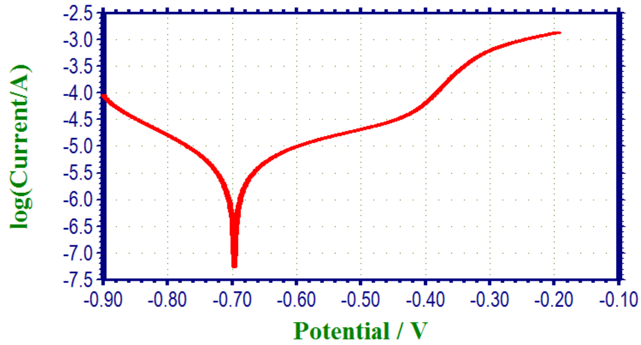

Figure 3. Polarization curves of MS is immersed in AU + 100ppm sodium chloride

Corrosion resistance of Ni-Ti superelastic alloy in AU in the presence of sodium chloride

The polarization curves of Ni-Ti super elastic alloy immersed in AU in the absence and presence of sodium chloride are shown in Fig. 8 The corrosion parameters namely *LPR*, I_{corr}, E_{corr}, Tafel slopes (b_c= cathodic, b_a= anodic) are given in Table.2. The polarization curves are shown in 4, 5 and 6.

Table 2. Corrosion parameters of Ni-Ti superelastic alloy immersed in AU in absence and presence of sodium chloride obtained by polarization study.

System	E_{corr} mv*	b_c mv**	b_a mv**	*LPR* Ω cm^2	I_{corr} A cm^{-2}
AU	-0.432	124	208	1.84x10^7	1.84x10^{-9}
AU+A	-0.493	121	304	1.93x10^7	1.95x10^{-9}
AU+B	-0.503	121	368	2.29x10^7	1.73x10^{-9}

AU=Artificial Urine; A=50ppm NaCl; B=100ppm NaCl; *mV vs SCE; ** mV in one decade.

It is observed from Table.2 that when 50 ppm of sodium chloride is added to AU, the *LPR* value increases from 1.84x10^7 to 1.93x10^7 Ω cm^2. Correspondingly the corrosion current (I_{corr}) decreases from 1.84x10^{-9} to 1.95 x10^{-9}A cm^{-2}. When 100ppm of sodium chloride is added to AU, the LPR value further increases to 2.29x10^7 ohmcm^2 and the corrosion current (I_{corr}) decreases to 1.73 x10^{-6} A cm^{-2}. In general it is observed that the corrosion resistance of Ni-Ti superelastic alloy in AU increases in the presence of sodium chloride.

It is observed from the table that the corrosion potential shifts to cathodic side (more negative) in the presence of sodium chloride. Hence it is concluded that in presence of sodium chloride, the cathodic reaction is controlled predominantly.

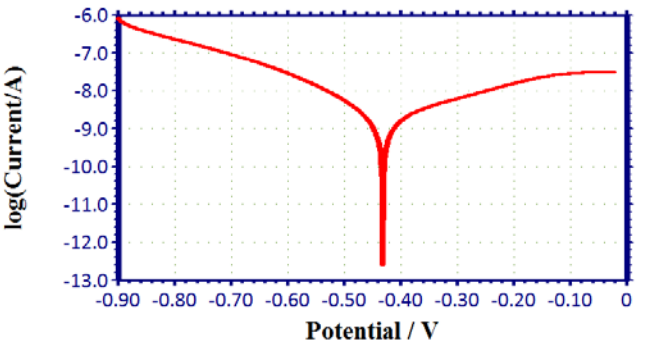

Figure 4. Polarization curves of Ni-Ti Super elastic is immersed in AU

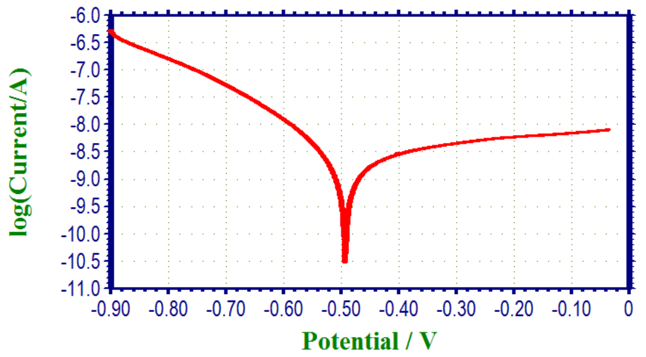

Figure 5. Polarization curves of Ni-Ti Super elastic is immersed in AU+50ppm sodium chloride

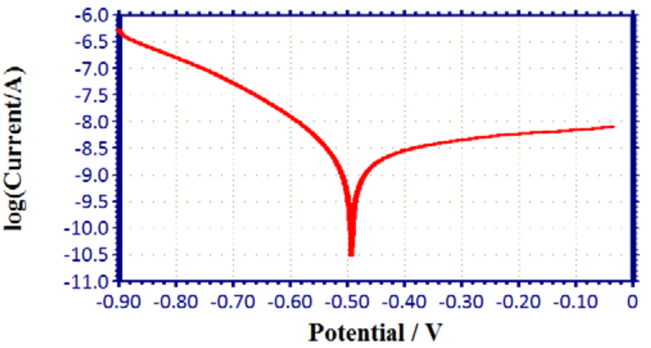

Figure 6. Polarization curves of Ni-Ti Super elastic is immersed in AU+100ppm sodium chloride

Conclusions

The corrosion behaviour of two metals namely mild steel (MS), Nickel-titanium super elastic alloy have been studied in artificial urine in the absence and presence of sodium chloride. Polarization has led to the following conclusions.

In the absence and presence of 50 ppm, 100 ppm of sodium chloride, the order of corrosion resistance was: Ni-Ti super elastic alloy > Mild steel.

Ni-Ti superelastic alloy was more corrosion resistant in the presence of sodium chloride than in its absence.

Mild steel was less corrosion resistant in the presence of sodium chloride than in its absence.

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